WG4 Preview

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ESPP ESG 2025 WG4
Relations with other fields of physics

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Chairperson: M. Karliner

Relations with other fields of physics

mostly Nuclear Physics (NP) & Astroparticle Physics (AP)
some Medical Physics (MP) + iNSPIRE HEP

WG4 mandate does not include ALICE 3, as it is a major LHC experiment, under review by CERN management

ESPP inputs: many proposals for additional activities CERN should consider in NP, AP, MP, e.g.

GW, DM, ν, cosmic rays, γ factory,
synergies with EIC, storage of very large data sets,
improve PET sensitivity via quantum entanglement...

Astroparticle

- Gravitational Wave experiments (GW):
  neutron star eq. of state from mergers ↔ high density QCD
  Einstein Telescope (ET)
  Document: "Synergies and complementariness with HEP"
  CERN holds a unique technological expertise of critical value for the design and construction of ground-based GW telescopes, esp. vacuum and cryogenic technology & expertise in tunnel construction. Financed by ET.
  3rd gen. projects such as ET → new cutting-edge technologies for CERN

  INFN: CERN should consider providing consolidated support to ET

  NL: establish joint vacuum platform, a la ν
  NO: engage on theory, phenomenology, and data analysis
  BE: CERN as initial incubator for ET, etc.

- DESY: high freq GW via axion infrastructure: beyond 10 kHz no astro sources expected; complementarity to large-scale interferometer exps. Exploring superconducting cavities and levitated sensors as GW probes.

AP continued

- Dark Matter (DM): constraints on DM from astrophysical data, indirect searches from γ-rays/nu-s from DM self-annihilations
  UK: establish joint cryogenics platform, a la nu

- Cosmology, CPV
  NO: CERN-TH to maintain world-class Cosmology & Gravitational Physics
  US: P5 & Astro 2020: CMB-S4

- nu Astrophysics: nu mass
  Opening CERN nu platform to selected non-accelerator exps
  CH: AP platform on basis of CERN nu platform
  Consider partnership with JP on Hyper-K
  NL: establish joint electronics and mechanical design platform, a la nu
  UK: establish joint AP cryogenics platform, a la nu
  UK: NP & AP should remain at around the current level

  US: P5 & Astro 2020: IceCube Gen2

BR: Angra experiment, for NUCLEAR MONITORING
Coherent nu scattering allows very portable detectors, ~3kg

AP continued

- Cosmic Rays

- Pierre Auger Observatory
  hadronic interactions, esp. p+O O+O @LHC, NA61/ASHINE
  crucial for muon puzzle in cosmic ray showers
  ↔ cosmic-ray interactions and their simulations,
  input to indirect DM searches + nu-N x-secs at ultra-high E

- 3 specific areas in which concrete synergies can be exploited:
  -- Hadronic Interaction Generators
  -- Collider Data for Hadronic Interactions in Air Showers
  -- Search for BSM effects, e.g.
    * breaking of Lorentz invariance → signatures in air showers
    * gamma rays and/or nu-s with E > 10^10 GeV from superheavies' decay
    * phase transitions in the early universe→ cosmic strings
    * cusps" → ultra energetic particles

NL: establish joint low power electronics platform, a la nu

AP continued

- gamma-ray research: construction and long-term operation of the Cherenkov Telescope Array (CTA) in both hemispheres. Acknowledging CTA within CERN's framework?

  Norway: Enable and support, at individual scientist/group level AP consortia, incl. CTA

- SPECTRUM project: EU-funded v. large datasets in AP & HEP for advancing Exabyte (10^9 GB) scale storage.

- formal recognition of AP EXPS? Implications? Cost? esp. European Strategy Forum on Research Infrastructures (ESFRI) Requested by several MS: DE, CZ, ES (ICTS), CH, SE, NL

- NL: include AP in ESPP. Next collider project should not come at expense of a diverse scientific programme in Europe

- BG: strong support for significant AP research. Active position and actions in operating small- to mid- scale facilities of CERN in other countries is seen as a possible and a highly desirable option.

AP continued

- AP Theory
  German AP [KAT]: CERN should host and support EuCAPT,
  European Consortium for Astroparticle Theory
  "CERN Neutrino Physics Centre" as EU hub

However...

UK: current level of CERN's engagement in AP, NP at valuable balance
(Not clear if consistent with proposal of nu-like addtnl platforms)

RS: NP, AP, computing, etc. should be pursued to a moderate extent.

GR: expanding too far beyond collider physics could stretch resources, esp. for FCC. CERN's primary focus should remain on its collider program.

FI: maintain current level of involvement in NP and AP exps, as well as in CLIMATE RESEARCH (CLOUD)

DK: To the extent that it does not significantly interfere (destructively) with CERN's core mission, activities to be driven by CERN users

SI: be careful not to dilute HEP; other fields should be kept in the same format as until now, based on mutual benefits and synergies.

Nuclear Physics

NuPECC: importance of the CERN AD/ELENA, ISOLDE, n_TOF, SPS fixed-target program and ALICE for European NP

CH: CERN should continue to support a broad range of low-energy NP initiatives. Organize existing AP efforts via a common interface. Current nu platform as seed for AP platform

AT: support Joint ECFA-NuPECC-ApPEC Seminar (JENAS)
& AD/ELENA, ISOLDE, n_TOF, SPS fixed target program, and ALICE

US: Long Range Plan for Nuclear Science (LRP), released Fall of 2023.
Two relevant items:
* How do quarks and gluons make up protons, neutrons, and, ultimately, atomic nuclei?
* How do we use atomic nuclei to uncover physics beyond the SM?
Concrete recommendations:
(1) Complete RHIC science program
(2) US-lead neutrinoless double beta decay campaign, ton-scale exps, using different isotopes and complementary techniques
(3) Expeditious completion of the Electron-Ion Collider (EIC)

CA: Developments in accelerator and detector technology likely to open opportunities for research in other fields, e.g.
-- new medical physics diagnostics and treatment.
-- applications supporting green technologies.
-- space systems designed for deep space exploration.
-- imaging and tomography instruments for material science.
Majority in favor of NP & AP at current level

JP: Synergy between femtoscopy at ALICE and Cusp Spectroscopy & YN Scattering at J-PARC

ALL:
collaboration on Detectors R&D
collaboration on accelerator R&D
collaboration on computing and software R&D
esp. EIC + LHeC: QCD in nuclear domain

Gamma Factory project: high-intensity polarized gamma beams from laser interaction with heavy ions at SPC and LHC.
7 orders of magnitude above current gamma ray sources.
Relevant for PP, NP, AP, accelerator and atomic physics.
New opportunities for nuclear power generation and nuclear medicine.

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Antiproton Decelerator: antimatter
Testing the Weak Equivalence Principle via antihydrogen in Earth's g g
Verifying CPT through precision spectroscopy techniques.

NO: support antimatter research

ISOLDE: fundamental symmetry studies using exotic nuclei and molecules (ß-decay, electric dipole moments), stellar nucleotsynthesis

n_TOF: neutron x-sections relevant to nuclear astrophysics, applications to emerging nuclear technology, hadron therapy and basic physics.

INFN TH: systematic measurements of nuclear reactions x-secs at low E extremely important to clarify issues in DM TH predictions

Atomic Physics

BSM from very sensitive atomic spectroscopy

Long-Baseline Atom Interferometry for fundamental physics, astrophysics and cosmology: searches for ultralight dark matter (ULDM) and for gravitational waves (GW) ~1 Hz, not covered by laser interferometry.

MAGIS detector under construction at Fermilab, MIGA detector in France. PX46 access shaft to the LHC identified as a v. suitable site for an atom interferometer of height ~ 100m, sites in UK & CanFranc Lab under investigation, possible sites for km-class detectors suggested.

Terrestrial Very-Long-Baseline Atom Interferometry (TVLBAI) proto-Collaboration: programme of interferometers of increasing baselines.

Medical Physics

CERN-MEDICIS: isotope mass separation facility→ innovative radionuclides
-- Ac-225: targeted alpha therapy.
-- Ra-223,224, 225: direct alpha emitters in targeted alpha therapy.
-- High Molar Activity Sm-153: pain relief in cancer patients
-- Tm/Er-165: Molecular imaging and therapeutic interventions

BE: upgrade MEDICIS (& coop. w. ISOL@MYRRHA at SCK CEN in BE)

PK: joint radiopharmaceutical research + PET/SPECT

#111: Potentially dramatic improvement of PET sensitivity via HEP exp techniques. Significant portion of signal information is lost due to photon scattering. Proposal to exploit quantum entanglement of the two photons.

BUT…

summary of MS inputs

many MS:

- need to balance these proposals vs. already stretched resources and focus on core business of CERN, i.e. collider physics & maintain non-collider program in PP

- CERN should maintain involvement in exp. NP & AP at current level

some MS:

- enhance engagement in AP via ν-like platform;
- some others: cryogenics platform, NP, MP...

→ consensus
based on majority of national inputs,
incl. APECC & NuPECC

existing non-collider experiments at CERN should be supported, as long as they do not take too many resources away, but CERN should not engage in additional non-particle physics experimental and/or hardware activities, unless they have a significant added value for its main mission, to carry out accelerator-based research, as specified by the CERN Convention.

CERN TH

- support of CERN experimental activity

- attract the brightest TH talents, maintain leading position in TH HEP worldwide

- many areas of NP & AP potentially of central importance to HEP

NP & AP @ CERN TH

samples of NP & AP issues of central importance to HEP

- disentangling purely nuclear effects in ν osc. exps
- nuclear enhancement of CPV
- BSM effects that might be observable in NP exps
- constraints on neutrinos, axions & DM from AP
- observational cosmology $\rightarrow$ inflation, DM, BSM,…
- neutron stars mergers via GW $\rightarrow$ EOS $\leftrightarrow$ high-density QCD

iNSPIRE HEP database

indispensable research tool

for HEP EXP & TH

but SLAC & DESY involvement now reduced

→ we have to find a way to support it